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Carbon emission mitigation measures in Brazil—case study of biomass policy for a ferroalloy plant in Ceará State

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Abstract

The present work aims at discussing the possibilities of atmospheric carbon emissions mitigation in the scope of the United Nations Framework Convention on Climate Change (UNFCCC) in the forest sector using a case study in the Northeast of Brazil. Taking Ceará State as an example and based on the Ceará State Energy Balances for 1980, 1984 and 1987, the Carbon (C-CO_2) Emission Balances were drawn up covering these same years. An exercise was carried out in order to draw up carbon emissions mitigation proposals through both Environmental Education and reforestation policies replacing forest clearing. The first, environmental education and forest management practices, involves more efficient practices in the woody sector. The second, reforestation policies, instead of felling native forests for fuel-wood burned to produce charcoal, is discussed from the economic point of view. An estimate was drawn up of the carbon abatement costs, using a case study for charcoal production based on reforestation instead of deforestation, for a ferroalloy plant in Ceará State.

Keywords: Biomass; Carbon mitigation; Ferroalloy sector; Charcoal; Deforestation; Environmental policy

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1. Introduction

Brazil is the second in the ranking of iron production in the world, being responsible for around 20% [1] of the global iron production. Although the Ceará State is not representative for this type of industry in Brazil, it was developed in the present work, an exercise as a case study in the Banabuiu Municipality of Ceará, taking into account a pig iron industry located in this city, to use as an example for the construction of baselines methodology for small scale projects in the context of the Clean Development Mechanism being implemented by the United Nations Framework Convention on Climate Change—UNFCCC.

Table 1 shows that the main emission percentages by sectors and sources in Ceará for the years 1980, 1984 and 1987 [2] were referred to the use of fuel-wood plus charcoal by the residential, ranching, farming and industrial sectors, followed by diesel oil and gasoline fuelling the transportation sector. The Carbon Emission Balances built in this exercise were based in the Energy Balances of Ceará State, for years 1980, 1984, 1987 because after the privatization of the Electric Energy Company of Ceará, it has been difficult to obtain new data about this subject.

A forest police for Brazil has been a subject of discussion in several areas of study, mainly because of the forest use for energy source, (fuel wood and charcoal) and the implications of this use. In Brazil, the charcoal production employs around 2,50,000 people, direct and indirectly (around 1,30,000 directly, in 1999) [3]. In 1995, charcoal was responsible for 47.9% of the Brazilian wood energy use and, as we can observe in Table 2, about 48% of which was produced from the native forest and 52% from the homogeneous planted forest for the same year 1995. From 1986 to 2003 the percentual relation of native and planted forest was changed. The year 1986 shows 82.7% for charcoal from native forest and 17.3% for charcoal from planted forest. The year 2003 shows a huge different

Table 1
Emission percentages of C-CO_2, by sector and by source in the years 1980, 1984, 1987 in the Ceará State, Brazil

Curse	Sector	Year 1980 (%)	Year 1984 (%)	Year 1987 (%)
Diesel oil	Transportation	20	19	16
Diesel oil	Agriculture and pasture	0	0	4
Oil	Transportation	15	11	8
LPG (propane butane gás)	Residential	5	7	8
Charcoal	Residential	7	0	7
Charcoal	Industrial	0	4	5
Charcoal	Energy	0	8	0
Wood fuel	Residential	11	11	13
Wood fuel	Agriculture and pasture	5	6	5
Wood fuel	Industrial	9	10	12

Source: Muylaert based on Energy Balances of Ceará State, 1989. Obs: after the privatization of energy sector in Brazil some companies do not deliver new energy balances such as the case of Ceara Energy Company (COELCE).

tendency in percentages: charcoal from native forest was responsible for 26.1% and charcoal from planted forest was responsible for 73.9% [4].

In the 1980s, for this increasing participation of silviculture to charcoal production, 83% of all tree plantations in Latin America were in southeastern Brazil. Brazil is also the biggest charcoal producer in the world; during 1991–93 its participation represented 28% of the worldwide total, with a production of 31 millions of cubic meters or 8.5 millions of metric ton of charcoal. In the Brazilian's iron and steel industry the charcoal is used for

Table 2
Evolution of deforestation of native forests and reforestation for charcoal use in Brazil

Year	Charcoal from native forest	%	Charcoal from planted forest	%
1986	29,049,000	82.7	6,065,000	17.3
1987	27,725,000	80.7	6,624,000	19.3
1988	28,563,000	78.0	8,056,000	22.0
1989	31,900,000	71.2	12,903,000	28.8
1990	24,355,000	66.0	12,547,000	34.0
1991	17,876,000	57.7	13,102,000	42.3
1992	17,826,000	61.1	11,351,000	38.9
1993	17,923,000	56.5	13,777,000	43.5
1994	15,180,000	46.0	17,820,000	54.0
1995	14,920,000	48.0	16,164,000	52.0
1996	7,800,000	30.0	18,200,000	70.0
1997	5,800,000	25.0	17,800,000	75.0
1998	8,600,000	32.6	17,800,000	67.4
1999	8,070,000	30.0	18,830,000	70.0
2000	7,200,000	28.3	18,200,000	71.7
2001	8,367,000	31.9	17,853,000	68.1
2002	7,571,000	28.2	19,249,000	71.8
2003	7,616,000	26.1	21,586,000	73.9

(Unit: mdc, meters of charcoal). Source: AMS-Associação Mineira de Silvicultura, 2004.

thermo-reduction. In 1995, the products manufactured with charcoal represent 30% of the pig iron industry, 14.6% of steel production, and 98% of the ferroalloys' production. It is important to observe that the efficiency of carbonization process is little and it is necessary to invest in new technologies and methods to produce charcoal [5], mainly if we take into account that the charcoal represents 60–70% of the price of pig iron production.

2. Background information on Ceará State

In 2000, the population of Ceará State was estimated at 7.4 million inhabitants, accounting for some 4.2% of the Brazilian population and covering an area of 1,45,711.8 km^2 with a density of 43.50 inhabitants/km^2. The State Gross Domestic Product (GDP) has increased 50% from 1986 to 1994, holding a 1.5% share in the Brazilian GDP (1995) [3].

Covered almost completely by *caatinga* scrublands, some 85% of the original forestlands of Ceará State have been destroyed, with deforestation clearing away secondary growth at a rate calculated at around 2,00,000 ha a year, according to data issued by the Brazilian Institute of Geography and Statistics (IBGE) for 1986/1987 [6].

The public sector in Ceará State rates combating drought and poverty as top priority in terms of government policies, although measures related to environmental issues have also been well to the fore recently. The uses of renewable and alternative sources of energy in Ceará are good examples of programs that help to the reduction greenhouse gases (GHG) emissions.

3. Carbon emission mitigation proposals

This section discusses two measures of carbon emission mitigation in the case study of Ceará. The first one deals with environmental education in the woody sector and the second one deals with the shifting from native forest to reforestation practice to charcoal production. The case study is a ferroalloy plant in the Banabuiú District in Ceará state in Brazil.

3.1. Carbon emission mitigation proposal through environmental education

Some important comments on land-use practices in Ceará State are pointed out aiming at to propose different practices to the sector with the objective of reducing carbon emissions [7].

The rural population of Ceará is very poor, selling fuel-wood for additional income. The population is involved in predatory logging practices, due to a lack of information. This picture shows that environmental policies have to deal with this social condition. It is not easy to substitute the practice of deforestation for the practice of plantation.

Drought is leaving the soil more saline, worsened by irrigating arable land for agricultural purposes and herbicides are used to an excessive extent what increases the greenhouse gases (GHG) emissions other than CO_2 such as N_2O.

Widespread mechanical felling techniques and felling by hand are undertaken in an inadequate manner and large-scale deforestation clears the land in an inadequate manner, through uncontrolled burn-offs. Both practices create favorable conditions to higher GHG emissions.

The data on Woody *Caatinga* Species Control Practices for wood exploration purposes in Ceará State indicate several physical control methods that have already been tested with *caatinga* vegetation. Resulting in lower carbon emissions, they constitute an indirect advantage, although difficult to be measured in quantitative terms.

As widespread poverty in Ceará State does not allow much emphasis to be placed on a carbon emissions mitigation policy, unless associated with other measures that are rated as higher priority from the social standpoint, *caatinga* reforestation policy incentives are the main steps implemented, in addition to rural community education programs that include measures such as explanatory pamphlets produced at the town council level in order to:

i. Upgrades the efficiency of fuel wood or charcoal-fired stoves;
ii. Encouraging the use of manual drills in parallel to a policy explaining how to use this technique in order to ensure widespread plant renewal;
iii. Explanations on how to use burn-offs in parallel to adequate fire-control measures.

3.2. Carbon emission mitigation proposal through reforestation policies (replacing native forest clearing)

The use of charcoal and wood fuel in Ceará in 1987 represents around 17% for industrial sector (Table 1). Table 3 presents the charcoal consumption by industrial sector in Ceará State for the years 2000–2003. It can be observed the importance of the pig iron independent sector followed by the steel integrated mills and the ferroalloys in the use of the charcoal.

A specific proposal to be analyzed was selected for a private industrial sector in the Municipality of Banabuiu, Ceará. Banabuiu has 1220 km^2 and 16,173 inhabit. Based on the hypothesis of using forest-clearing to produce charcoal, this proposal addresses

Table 3
Charcoal consumption by industrial sector in Brazil from 2000 to 2003

Industrial sector	2000	%	2001	%	2002	%	2003	%
Steel integrated mills	3750	14.8	3900	14.9	3681	13.7	3383	11.6
Independent production of pig iron of pig iron	16,400	64.6	17,580	67	18,032	67.2	20,220	69.2
Ferroalloys	2250	8.9	2800	10.7	2874	10.7	3164	10.8
Primary metals	–	–	365	1.4	233	0.9	302	1.0
Others	3000	11.8	1575	6	2000	7.5	2133	7.3
Total	25,400	100.0	26,220	100	26,820	100.0	29,202	100.0

Unit: 10^6 mdc. Source: AMS, 2004 based on Sindifer; Abrafe; IBS, 2004.

a ferroalloy plant in the Banabuiú District of Ceará State, which consumes 12,600 ton a year of charcoal as raw material for a furnace (corresponding to some 1.25% of total carbon emissions by this State in 1987). Its expansion plan covers a total of four furnaces.

(A) Calculation of the number of hectares that would have to be cleared (from native forest) to fuel a furnace at a ferroalloy plant in the Banabuiú District.

Data taken under consideration [6]:

✓ 12,600 ton/year of charcoal
✓ Timber density: 350 kg/m^3 (0.35 ton/m^3)
✓ Timber-mass yield: 41%
✓ Biomass density (native forest) in Ceará State: 80 m^3 timber/ha (28 ton/ha)

Calculation of (native forest) area cleared:

- Timber calculation: 12,600 ton/year of charcoal/0.41 = 30,732 ton/year of timber
- calculation of the area cleared: 30,732 ton/year/28 ton/ha (approximately 1100 ha/year of cleared forest needed to supply one furnace)

(B) Calculation of the timber and charcoal in ton equivalent petroleum (TEPs):
Data [8]:

✓ 1 ton of timber = 0.306 TEPs
✓ 1 ton of charcoal = 0.63 TEPs
- 30,732 ton of timber × 0.306 TEP/ton = 9404 TEP of timber
- 12,600 ton of charcoal × 0.63 TEP/ton = 7938 TEP of charcoal.
- 9404 TEPs of timber goes to the charcoal kilns and produces 7938 TEPs of charcoal, resulting in a loss of 1466 TEPs)

(C) Calculation of carbon emissions:
Data [9]:

✓ Coefficient tonC/TEP from timber pyrolysis = 0.183
✓ Coefficient tonC/TEP of charcoal = 1.243
Calculation:
✓ 9404 TEPs of timber × 0.183 = 1721 tonC emitted/year (pyrolysis)
✓ 7938 TEPs of charcoal × 1.243 = 9867 tonC emitted/year (combustion)
✓ TOTAL carbon emissions = 11,588 tonC/year (1 furnace)

(D) Calculation of reforestation and wood carbonization cost:
Data [9]:

✓ Productivity taken for reforestation: 15 ton/ha year
✓ Calculation of the reforestation area: 30,732 ton/year of timber (see Item A)/15 ton/ha year = 2049 ha
✓ Timber production cost: US$ 870/ha

✓ Total cost for carbonization: US$ 10.66/TEP of charcoal (carbonization cost: US$ 6.16/TEP of charcoal + investment cost in the carbonization process: US$ 4.5/TEP of charcoal)

If we assume that the industry in question uses timber from clear-cutting 1100 ha per year, a carbon emissions mitigation measure may be proposed that consists of reforesting 2049 ha at a cost [10] of:

✓ Year 1—US$ 1300
✓ Year 7—US$ 400/(1.1)^7 = US$ 205.13
✓ Year 14—US$ 400/(1.1)^14 = US$ 105.26
✓ Year 21—US$ 100/(1.1)^21 = US$ 54.05
✓ Current Value (Principal) = US$ 1664.44
✓ Annual Cost (over 21 years) = Current Value × Series Annual Factor = 0.1137 (i = 10%) [11].
✓ Annual Cost = US$ 1664.44 × 0.1137 = US$ 189.37/ha (over 21 years)

Over the next 7 years, the industry will have a cost of:

- US$ 10.66/TEP of charcoal × 7938 TEPs/year = US$ 84,619/year (carbonization)
- US$ 189.37/ha/year × 2049 ha = US$ 388,019/year (reforestation)
- Clear-cutting cost = 65% of reforestation cost = US$ 252,212/year (clear-cutting)
- Total cost for the industry (first 7 years) = US$ 724,850/year (total)

Carbon mitigation cost calculation:

$$(\mathrm{Cd} - \mathrm{Ca})/(\mathrm{Ea} - \mathrm{Ed})$$

Cd = industry cost after reforestation
Ca = industry cost before reforestation project (Two hypotheses will be drawn up)
Ed = Carbon emissions after reforestation project = 0 tonC

It can be noted that Carbon emissions from biomass burned in the furnace are assumed to be offset by carbon absorption through photosynthesis during the reforestation process [12].

Ea, Carbon emissions before reforestation project = 11,588 tonC (pyrolysis + combustion deriving from forest clearing)

It is important to note that Carbon emissions by a furnace at this plant reach 11,588 ton/year. Expansion to four furnaces would result in emissions of 46,352 ton, accounting for some 5% of total carbon emissions in 1987 by Ceará State.

Hypothesis 1—considering the previous costs for the industry, such as the wood carbonization cost plus deforestation cost and the subsequent costs such as the sum of the wood carbonization cost plus the deforestation cost (which we consider here as being

equal to the clear-cutting cost of native forest) plus the added cost of reforestation, we have: (over the first 7 years)

$$
\begin{aligned}
Ca &= \text{US\$ 336,831/year} = (\text{carbonization} + \text{clear-cutting of native forest})\\
Cd &= \text{US\$ 724,850/year (reforestation} + \text{carbonization} + \text{deforestation)}\\
Cd - Ca &= \text{US\$ } (724{,}850 - 336{,}831) = \text{US\$ 388,019/year}\\
Ea - Ed &= (11{,}588 - 0) \text{ tonC} = 11{,}588 \text{ tonC/year}
\end{aligned}
$$

Mitigation cost for Hypothesis 1:
US$ 388,019/11,588 tonC = US$ 33.45/tonC

Hypothesis 2—based on the assumption for the previous cost that this plant purchased charcoal at US$ 42.60/t and that the plant produces charcoal through reforestation for the subsequent cost, this results in the following: (over the first 7 years). The price estimated for charcoal from native forest plus taxes for 2004, was based on AMS [4].

$$
\begin{aligned}
Ca &= 12{,}600 \text{ ton Charcoal/year} \times \text{US\$ 42.60/ton Charcoal} = 536{,}760 \text{ US\$/year}\\
Cd &= \text{US\$ 724,850/year (reforestation } + \text{carbonization } + \text{deforestation)}\\
Cd - Ca &= \text{US\$ } (724{,}850 - 536{,}700) = \text{US\$ 188,090/year}\\
Ea &= 11588 \text{ tonC/year}\\
Ed &= 0 \text{ tonC/year}\\
Ea - Ed &= 11{,}588 \text{ tonC/year}
\end{aligned}
$$

Mitigation cost for Hypothesis 2:
US$ 188,090/11,588 tonC = US$ 16.23/tonC

Some assumptions were made for the present study. Related to the criteria for fuel wood, it was considered that part of it is directly consumed (with CO_2 emission coefficient = 1.178) and the other part is transformed in charcoal (identified in the Energy Balance in the 'transformation sector' in the line of charcoal process). It was considered the 'pyrolisis' as the method for this transformation process, which coefficient tonC/TEP is = 0.183.

As it was not observed the use of carbon emissions sources in the 'transformation sector' (such as diesel oil and others) related to electric generation, it was considered that the electric production is made, basically, by renewable source (for example, hydroelectric or from the use of biomass).

It was considered that 80% of the fuel wood for residential use is renewable.
It was considered that 20% of the fuel wood for industrial use is renewable.
It was considered that 100% of the charcoal consumed is not renewable.

4. Conclusions

Carbon emissions from the use of fuel-wood plus charcoal due to the industrial sector are quite important for Ceará (approximately 12%). Part of these emissions is related to iron and steel industries which can use fossil fuel (coke) or

renewable fuel such as charcoal or wood for thermo-reduction. Charcoal production activity involves two possibilities: plantation or deforestation of native forests. From 1986 to 2003 the percentual relation of native and planted forests was completely reversed. The year 1986 shows 82.7% for charcoal from native forest and 17.3% for charcoal from planted forest and the year 2003 shows that charcoal from native forest was responsible for 26.1% and charcoal from planted forest was responsible for 73.9%. It is important to stimulate new policies to reinforce this tendency and to diminish the deforestation process in Brazil. The ferroalloy sector can be an important example for that, using renewable charcoal.

Environmental education policies targeting the rural sector, presented in the Section 3.1, can promote a more awareness about the importance of more efficient energy use in forest stewardship practices also for the case study of this work, ferroalloy sector. A huge number of labors are involved in charcoal production in Brazil, greatest part used in the ferroalloy sector in which pertinent proposals can usher in other social and environmental advantages for Brazil such as job creation and income generation while reducing carbon emissions into the atmosphere.

The mitigation costs for the iron and steel sectors, however, US$ 33.45/tonC and US$ 16.23/tonC under the two hypotheses (comparison of charcoal from native and planted forests), presented in the Section 3.2 are factors that discourage investments in initiatives at present designed to reduce carbon emissions by both the private and public sectors in Brazil, particularly as this is not rated as a priority at either the state or national levels. Besides, the international price of coke (not issued by this work) regulates the industries' choice for thermo-reduction fuels. The Clean Development Mechanism (CDM) could offer an opportunity to shift the use of fossil fuel to renewable fuel since it foresees the creation of 'carbon credits' to be traded in international markets. Nevertheless this mechanism is still currently being regulated by the CDM Executive Board which is covered in the Kyoto Protocol not ratified until now.

International carbon market has been lining up flexible new tools for financing projects that reduce carbon emissions, independently of the official recognition of Kyoto Protocol. Nevertheless, the price of a certified emission reduction for 1 ton of CO2 is estimated in US$ 0.96 according to the Chicago Climate Exchange [13], too much inferior in comparison with the abatement costs studied in the present work.

Annexes. Ceará State energy balances—1980, 1984 and 1987. Carbon emissions (tonC/TEP—ton of carbon/ton equivalent petroleum)

Annexes 1–3.

Annex 1
Ceará State—consumption by sector—year:1980

Sources	Coefficient (tonC/TEP)	Residential (10^3 TEP)	Residential (10^3 tonC)	Commercial (10^3 TEP)	Commercial (10^3 tonC)	Government (10^3 TEP)	Government (10^3 tonC)	Agriculture (10^3 TEP)	Agriculture (10^3 tonC)	Transportation (10^3 TEP)	Transportation (10^3 tonC)	Industry (10^3 TEP)	Industry (10^3 tonC)	Energy (10^3 TEP)	Energy (10^3 tonC)	Fuel-wood/charcoal (10^3 TEP)	Fuel-wood/charcoal (10^3 tonC)	Transference loss (10^3 TEP)	Transference loss (10^3 tonC)	Total (10^3 TEP)	Total (10^3 tonC)	Source (%)
Secondary																						
Diesel Oil	0,846	0,00	0,00	3,40	2,88	0,80	0,68	16,90	14,30	189,70	160,49	20,20	17,09	22,80	19,29	0,00	0,00	0,80	0,68	254,60	215,39	28
Fuel Oil	0,888	0,00	0,00	0,90	0,00	0,00	0,00	0,00	0,00	9,50	8,44	65,20	57,90	8,50	7,55	0,00	0,00	0,00	0,00	84,10	73,88	9
Gasoline	0,791	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	149,80	118,49	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	149,80	118,49	15
LPG	0,720	56,50	40,68	1,20	0,86	0,00	0,00	0,00	0,00	0,00	0,00	1,20	0,86	0,00	0,00	0,00	0,00	0,00	0,00	58,90	42,41	5
Kerosene	0,816	17,80	14,52	10,50	8,57	0,00	0,00	0,00	0,00	28,10	22,93	0,80	0,65	0,00	0,00	0,00	0,00	0,00	0,00	57,20	46,68	6
Charcoal	1,243	46,20	57,43	2,50	0,00	0,00	0,00	0,50	0,62	0,00	0,00	6,00	7,46	0,00	0,00	0,00	0,00	0,00	0,00	55,20	65,51	8
Primary																						
Natural Gas	0,690	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0
Fuel-wood (deforestation)	1,178	70,42	82,95	0,60	0,71	0,10	0,12	36,30	42,76	0,00	0,00	59,28	69,83	0,00	0,00	0,00	0,00	0,00	0,00	166,70	196,37	25
Fuel-wood (pyrolysis)	0,183	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	110,90	20,29	0,00	0,00	110,90	20,29	3
Total		190,92	195,59	19,10	13,02	0,90	0,79	53,70	57,68	377,10	310,34	152,68	153,79	31,30	26,84	110,90	20,29	0,80	0,68	937,40	779,02	100
Sector (%)			25		2		0		7		40		20		3		3		0		100	

Source: table created by the authors, based in the Energy Balance of Ceará State in 1980, published by COELCE, 1989.

Annex A2
Ceará State-Consumption by Sector-year: 1984

Sources	Coefficient (tonC/TEP)	Residential (10^3 TEP)	Residential (10^3 tonC)	Commercial (10^3 TEP)	Commercial (10^3 tonC)	Government (10^3 TEP)	Government (10^3 tonC)	Agriculture (10^3 TEP)	Agriculture (10^3 tonC)	Transportation (10^3 TEP)	Transportation (10^3 tonC)	Industry (10^3 TEP)	Industry (10^3 tonC)	Energy (10^3 TEP)	Energy (10^3 tonC)	Fuel-wood/charcoal (10^3 TEP)	Fuel-wood/charcoal (10^3 tonC)	Total (10^3 TEP)	Total (10^3 tonC)	Source (%)
Secondary																				
Diesel Oil	0,846	0,00	0,00	3,60	3,05	0,90	0,76	28,00	23,69	171,70	145,26	13,60	11,51	17,40	14,72			235,20	198,98	26
Fuel Oil	0,888	0,00	0,00	0,00	0,00	0,90	0,80	0,00	0,00	14,30	12,70	29,40	26,11	8,90	7,90			53,50	47,51	6
Gasoline	0,791	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	108,70	85,98	0,00	0,00	0,00	0,00			108,70	85,98	11
LPG	0,720	75,70	54,50	1,50	1,08	0,60	0,43	0,00	0,00	0,00	0,00	1,80	1,30	0,00	0,00			79,60	57,31	7
Kerosene	0,816	7,20	5,88	4,20	3,43	0,00	0,00	0,00	0,00	28,40	23,17	3,20	2,61	0,00	0,00			43,00	35,09	5
Charcoal	1,243	3,00	3,73	0,00	0,00	0,00	0,00	0,70	0,87	0,00	0,00	25,70	31,95	49,60	61,65			79,00	98,20	13
Primary																				
Natural Gas	0,690	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,80	1,24			1,80	1,24	0
Fuel-wood (deforestation)	1,178	74,96	88,30	0,70	0,82	0,10	0,12	42,30	49,83	0,00	0,00	65,36	76,99	0,00	0,00			183,42	216,07	28
Fuel-wood (pyrolysis)	0,183															153,30	28,05	153,30	28,05	4
Total		160,86	152,41	10,00	8,38	2,50	2,11	71,00	74,39	323,10	267,11	139,06	150,46	77,70	85,52	153,30	28,05	937,52	768,42	100
Sector (%)			20		1		0		10		35		20		11		4		100	

Source: table created by the authors, based in the Energy Balance of Ceará State in 1984, published by COELCE, 1989.

Annex A3
Ceará State-Consumption by Sector-year: 1987

Sources	Coefficient (tonC/TEP)	Residential (10^3 TEP)	Residential (10^3 tonC)	Commercial (10^3 TEP)	Commercial (10^3 tonC)	Government (10^3 TEP)	Government (10^3 tonC)	Agriculture (10^3 TEP)	Agriculture (10^3 tonC)	Transportation (10^3 TEP)	Transportation (10^3 tonC)	Industry (10^3 TEP)	Industry (10^3 tonC)	Energy (10^3 TEP)	Energy (10^3 tonC)	Fuelwood/charcoal (10^3 TEP)	Fuelwood/charcoal (10^3 tonC)	Total (10^3 TEP)	Total (10^3 tonC)	Source (%)
Secondary																				
Diesel Oil	0,846	0,00	0,00	4,00	3,38	0,90	0,76	51,00	43,15	183,60	155,33	11,40	9,64	33,00	27,92	0,00	0,00	283,90	240,18	25
Fuel Oil	0,888	0,00	0,00	0,90	0,00	1,20	1,07	0,00	0,00	14,70	13,05	30,30	26,91	11,20	9,95	0,00	0,00	58,30	50,97	5
Gasoline	0,791	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	98,80	78,15	0,00	0,00	0,00	0,00	0,00	0,00	98,80	78,15	8
LPG	0,720	112,40	80,93	1,80	1,30	0,00	0,00	0,00	0,00	0,00	0,00	1,20	0,86	0,00	0,00	0,00	0,00	115,40	83,09	9
Kerosene	0,816	10,20	8,32	2,10	1,71	0,00	0,00	0,00	0,00	34,30	27,99	0,70	0,57	0,00	0,00	0,00	0,00	47,30	38,60	4
Charcoal	1,243	52,50	65,26	3,50	0,00	0,00	0,00	0,50	0,62	0,00	0,00	37,70	46,86	0,00	0,00	0,00	0,00	94,20	112,74	12
Primary																				
Natural Gas	0,690	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	16,40	11,32	11,90	8,21	0,00	0,00	28,30	19,53	2
Fuelwood (deforestation)	1,178	101,44	119,50	1,10	1,30	0,10	0,12	41,30	48,65	0,00	0,00	93,44	110,07	0,00	0,00	0,00	0,00	237,38	279,63	30
Fuelwood (pyrolysis)	0,183	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	181,80	33,27	181,80	33,27	4
Total	1,166	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	7,30	8,51	0,00	0,00	0,00	0,00	7,30	8,51	1
Sector (%)		276,54	274,01	13,40	7,69	2,20	1,94	92,80	92,42	331,40	274,52	198,44	214,75	56,10	46,07	181,80	33,27	1152,68	944,67	100

Source: table created by the authors, based in the Energy Balance of Ceará State in 1987, published by COELCE, 1989.

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